

$\Sigma_{1/2-}^*(1380)$ in the $\Lambda_c^+ \rightarrow \eta\pi^+\Lambda$ decay

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A Σ^* state with spin-parity $J^P = 1/2^-$ with mass and width around 1380 MeV and 120 MeV, referred to as the $\Sigma_{1/2-}^*(1380)$, has been predicted in several pentaquark models and inferred from the analysis of CLAS γp data. In the present work, we discuss how one can employ the $\Lambda_c^+ \rightarrow \eta\pi^+\Lambda$ decay to test its existence, as well as to study the $\Sigma^*(1385)$ state with $J^P = 3/2^+$. Because the final $\pi^+\Lambda$ system is in a pure isospin $I = 1$ combination, the $\Lambda_c^+ \rightarrow \eta\pi^+\Lambda$ decay can be an ideal process to study these Σ^* resonances. In particular, we show that the decay angle and energy distributions of the π^+ are very different for $\Sigma^*(1385)$ and $\Sigma_{1/2-}^*(1380)$. The proposed decay mechanism as well as the existence of the $\Sigma_{1/2-}^*(1380)$ state can be checked by future BESIII and Belle experiments.

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I. INTRODUCTION

Study of the spectrum of Σ^* states is one of the most important issues in hadronic physics [1, 2]. Σ^* states were mostly produced and studied in \bar{K} -induced reactions, and our knowledge on them is still rather limited [1–3]. In the low-lying energy region, only a few Σ^* excited states are well established, such as the $\Sigma^*(1385)$ of spin-parity $J^P = 3/2^+$, $\Sigma^*(1660)$ of $J^P = 1/2^+$, $\Sigma^*(1670)$ of $J^P = 3/2^-$, $\Sigma^*(1750)$ of $J^P = 1/2^-$, and $\Sigma^*(1775)$ of $J^P = 5/2^-$. The others are not well established and for some even their existence has not been confirmed [3]. Thus, more studies on Σ^* resonances both on theoretical and experimental sides are necessary.

Based on the penta-quark picture, a new Σ^* state with $J^P = 1/2^-$, referred to as the $\Sigma^*(1380)$, was predicted with mass around 1380 MeV [4]. Another more general penta-quark model [5] without introducing explicitly diquark clusters also predicts this new Σ^* state but with mass around 1405 MeV. The possibility for the existence of such a new $\Sigma^*(1380)$ state in J/ψ decays was pointed out in Refs. [6, 7]. Later on, the studies of the $K^-p \rightarrow \Lambda\pi^+\pi^-$ reaction have shown some further evidence for the existence of the $\Sigma^*(1380)$ state, yielding a mass around 1380 MeV and a width about 120 MeV [8, 9]. Furthermore, in Refs. [10–12], the role played by the new $\Sigma^*(1380)$ state in the $K\Sigma^*(1385)$ photo-production and $\Lambda p \rightarrow p\Lambda\pi^0$ reaction was studied, and it was shown that, apart from the existing $\Sigma^*(1385)$ resonance, there are signs of the $\Sigma^*(1380)$ state. Recently, the existence of an isospin $I = 1$ resonance in the vicinity of the $\bar{K}N$ threshold was studied in Ref. [13] based on the analysis of the CLAS data on the $\gamma p \rightarrow K^+\pi^\pm\Sigma^\mp$ reactions [14]. Such a state is also discussed in Refs. [15–17] within the unitary chiral perturbation theory. However, the existence of such an $I = 1$ state around the $\bar{K}N$ threshold is less clear since it depends on the details of the fits performed [17].

Clearly, it is helpful to check the validity of penta-quark models by studying the contributions of the $\Sigma^*(1380)$ state in different reactions. Because the mass of this new Σ^* state is close to the well established $\Sigma^*(1385)$ resonance, it will manifest itself in the production of the $\Sigma^*(1385)$ resonance and as a result an experimental study of the $\Sigma^*(1385)$ resonance might interfere with that of the $\Sigma^*(1380)$, because their mass overlaps and they share the same $\pi\Lambda$ decay mode.

Recently, it has been shown that the non-leptonic weak decays of charmed baryons are useful processes to study hadronic resonances, some of which are subjects of intense debate about their nature [18–20]. For instance, the $\Lambda_c^+ \rightarrow \pi^+MB$ weak decays were studied in Ref. [21], where M and B stand for mesons and baryons. It is shown there that these weak decays might be ideal processes to study the $\Lambda(1405)$ and $\Lambda(1670)$ resonances, because they are dominated by the isospin $I = 0$ contribution. In Ref. [22], the $\pi\Sigma$ mass distribution was studied in the $\Lambda_c^+ \rightarrow \pi^+\pi\Sigma$ decay with the aim of extracting the $\pi\Sigma$ scattering lengths. In a recent work [23] the role of the exclusive Λ_c^+ decays into a neutron in testing the flavor symmetry and final state interactions was investigated. It was shown that the three body non-leptonic decays are of great interest to explore final state interactions in Λ_c^+ decays. Along the same line, in Ref. [24], the $\Lambda_c^+ \rightarrow \pi^+\eta\Lambda$ decay was revisited taking into account both the $\eta\Lambda$ and $\pi^+\eta$ final state interactions. It was found that the $\pi^+\eta$ and $\eta\Lambda$ invariant mass distributions show clear cusp and peak structures, which can be associated with the $a_0(980)$ and $\Lambda(1670)$ resonances. These results clearly show that the Λ_c^+ decays provide an alternative useful source to obtain information on the structure of low lying hadronic states.

One should note that the above mentioned works [21, 24] considered only the color-favored external W -emission diagrams, but neglected the color-suppressed

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W -exchange diagrams [25, 26]. On the other hand, the experimental measurements of the decay modes of $\Lambda_c^+ \rightarrow (\pi\Sigma)^+$, $\eta\Sigma^+$, and $\eta\Sigma^{*+}$ [3, 27] indicate that the W -exchange diagrams, which are subject to color and helicity suppression, can become relevant in certain Λ_c^+ decay modes [28], where the external W -emission diagrams do not contribute. We note that recently the possibility of searching for Ξ_{bc}^0 and Ξ_{cc}^+ is explored in the W -exchange processes, $\Xi_{bc}^0 \rightarrow pK^-$ and $\Xi_{cc}^+ \rightarrow \Sigma_c^{*+}(2520)K^-$ [29].

In this work, we study the role of the $\Sigma_{1/2}^*(1380)$ in the $\Lambda_c^+ \rightarrow \eta\Sigma_{1/2}^*(1380) \rightarrow \eta\pi^+\Lambda$ decay, which can proceed via the external W -emission diagram, similar to the P_c states produced in the $\Lambda_b^0 \rightarrow K^-P_c^+$ decay [30]. Meanwhile, for comparison, we study the $\Lambda_c^+ \rightarrow \eta\Sigma^{*+}(1385) \rightarrow \eta\pi^+\Lambda$ decay, which is dominated by the W -exchange diagram [31].

This article is organized as follows. In Sec. II, we present the theoretical formalism of the $\Lambda_c^+ \rightarrow \eta\pi^+\Lambda$ decay. Numerical results and discussions are presented in Sec. III, followed by a short summary in Sec. IV.

II. FORMALISM

In this section, we introduce the theoretical formalism and ingredients to study the $\Lambda_c^+ \rightarrow \eta\pi^+\Lambda$ decay. In the following, we use Σ_1^* and Σ_2^* to denote the $\Sigma_{1/2}^*(1380)$ state and the $\Sigma^*(1385)$ resonance.

A. Feynman diagrams and decay amplitudes

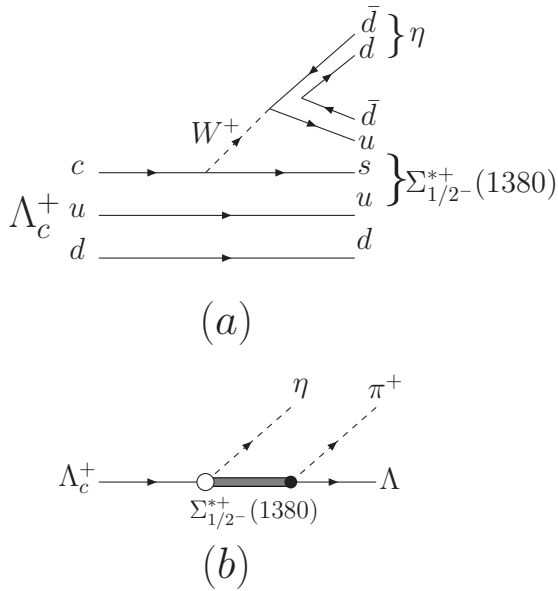


FIG. 1: Quark level diagram for $\Lambda_c^+ \rightarrow \eta\Sigma_{1/2}^*(1380)$ (a) and hadron level diagram for $\Lambda_c^+ \rightarrow \eta\Sigma_{1/2}^*(1380) \rightarrow \eta\pi^+\Lambda$ decay (b).

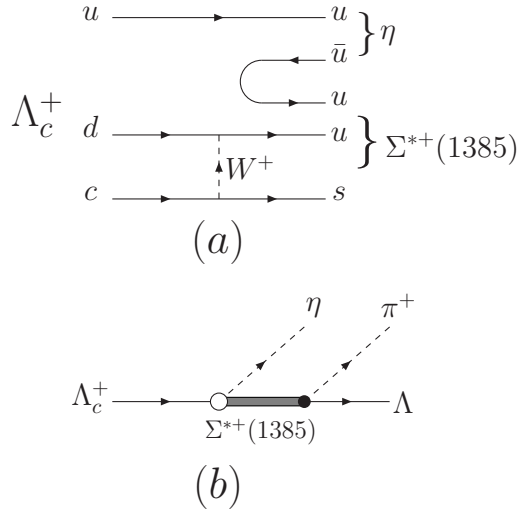


FIG. 2: Quark level diagram for $\Lambda_c^+ \rightarrow \eta\Sigma^{*+}(1385)$ (a) and hadron level diagram for $\Lambda_c^+ \rightarrow \eta\Sigma^{*+}(1385) \rightarrow \eta\pi^+\Lambda$ decay (b).

Because $\Sigma_{1/2}^*(1380)$ has a large five-quark component [4], it can be produced via the color-favored external W -emission diagram as shown in Fig. 1 (a). The hadron level diagram for the decay of $\Lambda_c^+ \rightarrow \eta\Sigma_{1/2}^*(1380) \rightarrow \eta\pi^+\Lambda$ is shown in Fig. 1 (b) with $\Sigma^{*+}(1380)$ decaying into $\pi^+\Lambda$.

The general quark level internal W -exchange diagram for the $\Lambda_c^+ \rightarrow \eta\Sigma^{*+}(1385)$ is shown in Fig. 2 (a). In principle, there are also penguin-type quark diagrams, which, however, can be neglected in charm decays due to Glashow-Iliopoulos-Maiani cancellation [31]. The decay of $\Lambda_c^+ \rightarrow \eta\Sigma^{*+}(1385) \rightarrow \eta\pi^+\Lambda$ at the hadron level is shown in Fig. 2 (b).

The general decay amplitudes for $\Lambda_c^+ \rightarrow \eta\Sigma_{1/2}^*(1380)$ and $\Lambda_c^+ \rightarrow \eta\Sigma^{*+}(1385)$ can be decomposed into two different structures as,

$$\mathcal{M}(\Lambda_c^+ \rightarrow \eta\Sigma_1^{*+}) = i\bar{u}(q)(A_1 + B_1\gamma_5)u(p), \quad (1)$$

$$\mathcal{M}(\Lambda_c^+ \rightarrow \eta\Sigma_2^{*+}) = \frac{i}{m_\eta}\bar{u}_\mu(q)p_1^\mu(A_2 + B_2\gamma_5)u(p), \quad (2)$$

where q , p , and p_1 are the momentum of Σ_1^{*+} or Σ_2^{*+} , Λ_c^+ , and η meson, the A_1 and B_1 are s -wave and p -wave amplitudes, while A_2 and B_2 are p -wave and D -wave amplitudes, respectively.

To get the whole decay amplitudes of the digrams shown in Figs. 1 (b) and 2 (b), we use the interaction Lagrangian densities of Refs. [32–35] for $\Sigma_1^*\pi\Lambda$ and $\Sigma_2^*\pi\Lambda$ vertexes,

$$\mathcal{L}_{\pi\Lambda\Sigma_1^*} = g_{\pi\Lambda\Sigma_1^*}\bar{\Sigma}_1^*\vec{\tau}\cdot\vec{\pi}\Lambda + \text{h.c.}, \quad (3)$$

$$\mathcal{L}_{\pi\Lambda\Sigma_2^*} = \frac{g_{\pi\Lambda\Sigma_2^*}}{m_\pi}\bar{\Sigma}_2^{*\mu}(\vec{\tau}\cdot\partial_\mu\vec{\pi})\Lambda + \text{h.c.}, \quad (4)$$

where Σ_1^* and $\Sigma_2^{*\mu}$ are the fields for $\Sigma^*(1380)$ and $\Sigma^*(1385)$, respectively.

The coupling constant $g_{\pi\Lambda\Sigma_2^*} = 1.26$ is determined from the experimental partial decay width of $\Sigma^*(1385) \rightarrow \pi\Lambda$ [3]. For $g_{\pi\Lambda\Sigma_1^*}$, we fix it to be 2.12 [11, 12], assuming that the $\Sigma^*(1380)$ total decay width, 120 MeV, is solely from the $\pi\Lambda$ decay.

The invariant decay amplitude of the $\Lambda_c^+ \rightarrow \eta\pi^+\Lambda$ is

$$\mathcal{M}_1 = ig_{\pi\Lambda\Sigma_1^*}\bar{u}(p_3)G^{\Sigma_1^*}(q)(A_1 + B_1\gamma_5)u(p), \quad (5)$$

$$\mathcal{M}_2 = \frac{ig_{\pi\Lambda\Sigma_2^*}}{m_\eta m_\pi}\bar{u}(p_3)p_2^\mu G_{\mu\nu}^{\Sigma_2^*}(q)p_1^\nu(A_2 + B_2\gamma_5)u(p), \quad (6)$$

where \mathcal{M}_1 and \mathcal{M}_2 stand for the contributions from $\Sigma_{1/2-}^*(1380)$ and $\Sigma^*(1385)$, respectively. In the above equations, p_2 and p_3 represent the 4-momenta of the final π^+ and Λ , respectively. The propagators for $\Sigma_{1/2-}^*(1380)$ and $\Sigma^*(1385)$ are as follows,

$$G^{\Sigma_1^*}(q) = i\frac{\not{q} + M_{\Sigma_1^*}}{q^2 - M_{\Sigma_1^*}^2 + iM_{\Sigma_1^*}\Gamma_{\Sigma_1^*}}, \quad (7)$$

$$G_{\mu\nu}^{\Sigma_2^*}(q) = i\frac{\not{q} + M_{\Sigma_2^*}}{q^2 - M_{\Sigma_2^*}^2 + iM_{\Sigma_2^*}\Gamma_{\Sigma_2^*}}P_{\mu\nu}, \quad (8)$$

with

$$P^{\mu\nu} = -g^{\mu\nu} + \frac{1}{3}\gamma^\mu\gamma^\nu + \frac{2q^\mu q^\nu}{3M_{\Sigma_2^*}^2} + \frac{\gamma^\mu q^\nu - \gamma^\nu q^\mu}{3M_{\Sigma_2^*}}, \quad (9)$$

where $M_{\Sigma_1^*}$ ($M_{\Sigma_2^*}$) and $\Gamma_{\Sigma_1^*}$ ($\Gamma_{\Sigma_2^*}$) are the mass and total decay width of $\Sigma_{1/2-}^*(1380)$ [$\Sigma^*(1385)$] resonance. We take $M_{\Sigma_1^*} = 1380$ MeV and $\Gamma_{\Sigma_1^*} = 120$ MeV as in Refs. [8, 9]. For $M_{\Sigma_2^*}$ and $\Gamma_{\Sigma_2^*}$, we take $M_{\Sigma_2^*} = 1382.8$ MeV and $\Gamma_{\Sigma_2^*} = 36$ MeV as in the PDG [3].

B. Invariant mass, decay angle and energy distributions

The $\pi^+\Lambda$ invariant mass distribution for the $\Lambda_c^+ \rightarrow \eta\pi^+\Lambda$ decay reads [3]

$$\frac{d\Gamma}{dM_{\pi^+\Lambda}} = \frac{m_\Lambda}{32\pi^3 M_{\Lambda_c^+}} \int \sum |\mathcal{M}|^2 |\vec{p}_1| |\vec{p}^*| d\cos\theta^*, \quad (10)$$

where $|\vec{p}^*|$ and θ^* are the three-momentum and decay angle of the outgoing π^+ (or Λ) in the center-of-mass (c.m.) frame of the final $\pi^+\Lambda$ system, $|\vec{p}_1|$ is the three-momentum of the final η meson in the rest frame of Λ_c^+ , and $M_{\pi^+\Lambda}$ is the invariant mass of the final $\pi^+\Lambda$ system.

The decay angle and energy distributions of the outgoing particle can be used to distinguish the intermediate Σ^* resonances with different spin and parity. In the present case, we are interested in $d\Gamma/d\cos\theta^*$, which reads

$$\frac{d\Gamma}{d\cos\theta^*} = \frac{m_\Lambda}{32\pi^3 M_{\Lambda_c^+}} \int \sum |\mathcal{M}|^2 |\vec{p}_1| |\vec{p}^*| dM_{\pi^+\Lambda} \quad (11)$$

The energy distribution of π^+ meson reads

$$\frac{d\Gamma}{dE_{\pi^+}} = \frac{m_\Lambda}{32\pi^3} \int \sum |\mathcal{M}|^2 dE_\Lambda, \quad (12)$$

where E_{π^+} and E_Λ are the energies of π^+ and Λ in the rest frame of Λ_c^+ .

III. NUMERICAL RESULTS AND DISCUSSION

In Fig. 3 we show the Dalitz Plot for $M_{\eta\pi^+}^2$ and $M_{\pi^+\Lambda}^2$ in the $\Lambda_c^+ \rightarrow \eta\pi^+\Lambda$ decay. If we take $M_{\pi^+\eta}^2 \sim 1.0$ GeV^2 , where the $a_0(980)$ meson gives significant contributions [24], we see that $M_{\pi^+\Lambda}^2$ goes from 1.6 GeV^2 to 3.0 GeV^2 , but the range is similar for other values of $M_{\pi^+\eta}^2$ in a wide range. This means that the strength of $\pi^+\Lambda$ invariant mass distribution will spread in a wide range of $M_{\pi^+\eta}^2$ and we expect that the contribution from the $a_0(980)$ state will behave roughly like a background following the phase space. Hence, in this work we do not consider the contribution from $a_0(980)$ in the calculation of the $\pi^+\Lambda$ invariant mass distribution.

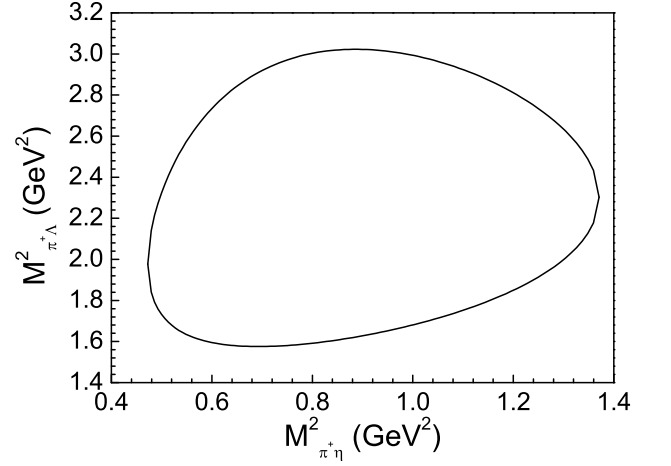


FIG. 3: Dalitz Plot for $\Lambda_c^+ \rightarrow \eta\pi^+\Lambda$ decay, in the $\pi^+\eta$ and $\pi^+\Lambda$ invariant masses square.

In Fig. 4 we show the Dalitz Plot for $M_{\eta\Lambda}^2$ and $M_{\pi^+\Lambda}^2$ in the $\Lambda_c^+ \rightarrow \eta\pi^+\Lambda$ decay. If we take $M_{\eta\Lambda}^2 \sim 2.8$ GeV^2 , where the $\Lambda(1670)$ resonance gives significant contributions [24], we see that $M_{\pi^+\Lambda}^2$ stays in a very narrow and high energy range from 2.9 GeV^2 to 3.0 GeV^2 , but we are interested in $d\Gamma/dM_{\pi^+\Lambda}$ in the range of $M_{\pi^+\Lambda}^2$ around 1.9 GeV^2 . Hence we expect that the contribution of the $\Lambda(1670)$ resonance will not affect in any significant way the $\pi^+\Lambda$ mass distribution and we neglected its contribution in this work.

In order to evaluate the invariant mass, decay angle, and decay energy distributions of $d\Gamma/dM_{\pi^+\Lambda}$, $d\Gamma/d\cos\theta^*$ and $d\Gamma/dE_{\pi^+}$ we have to know the values of A_1 , B_1 , A_2 and B_2 . Fortunately, we find that the shapes of the invariant mass, decay angle, and decay energy distributions of the A_1 (A_2) and B_1 (B_2) terms are similar and

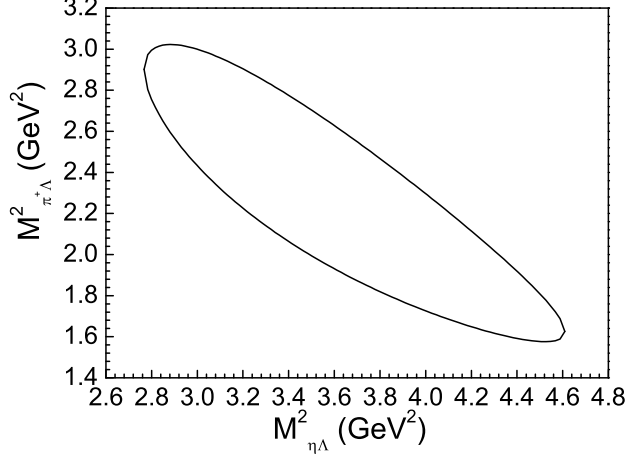


FIG. 4: Dalitz Plot for $\Lambda_c^+ \rightarrow \eta\pi^+\Lambda$ decay, in the $\eta\Lambda$ and $\pi^+\Lambda$ invariant masses square.

we take $A_1 = B_1$ and $A_2 = B_2$ in this work. They are also assumed to be constant.¹ From the Λ_c^+ total decay width $\Gamma_{\Lambda_c^+} = 3.29 \times 10^{-9}$ MeV and the branch ratio $\text{Br}[\Lambda_c^+ \rightarrow \eta\Sigma^{*+}(1385)] = 1.08\%$ [3], we obtain $A_2 = B_2 = 5.51 \times 10^{-7}$, using the following decay width formula

$$\Gamma[\Lambda_c^+ \rightarrow \eta\Sigma^{*+}(1385)] = \frac{A_2^2 |\vec{p}|}{3\pi} \times \frac{M_{\Lambda_c^+}^2 E^3 - 2M_{\Lambda_c^+} M_{\Sigma_2^*}^2 E^2 + M_{\Sigma_2^*}^4 E - m_\eta^2 M_{\Sigma_2^*}^2 E}{M_{\Lambda_c^+} m_\eta^2 M_{\Sigma_2^*}^2}, \quad (13)$$

with

$$E = \frac{M_{\Lambda_c^+}^2 + M_{\Sigma_2^*}^2 - m_\eta^2}{2M_{\Lambda_c^+}}, \quad (14)$$

$$|\vec{p}| = \sqrt{E^2 - M_{\Sigma_2^*}^2}. \quad (15)$$

First, we investigate the role of the $\Sigma^*(1385)$ and $\Sigma_{1/2}^*(1380)$ resonances in the invariant mass distribution of $d\Gamma/dM_{\pi^+\Lambda}$, which is shown in Fig. 5. The solid line stands for the result considering only the contribution from $\Sigma^*(1385)$ with $A_2 = B_2 = 5.51 \times 10^{-7}$. While the dashed curve stands for contributions from

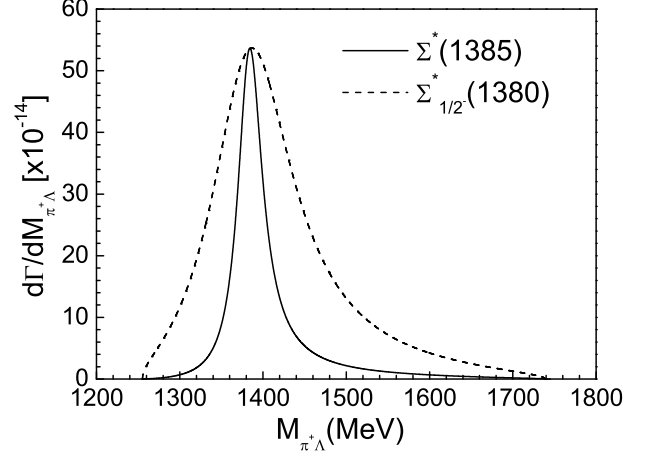


FIG. 5: Invariant mass distributions $d\Gamma/dM_{\pi^+\Lambda}$ as a function of $M_{\pi^+\Lambda}$.

only $\Sigma_{1/2}^*(1380)$. For comparison we normalize the two curves to the peak, which results in $A_1 = B_1 = 13.05 \times 10^{-7}$. From the figure we see that the contribution of $\Sigma_{1/2}^*(1380)$ makes the $\pi^+\Lambda$ mass distribution broader because of its relatively large decay width.

Because the $\Sigma^*(1385)$ resonance has spin-parity $3/2^+$, it decays into $\pi\Lambda$ in relative p -wave, while the $\Sigma_{1/2}^*(1380)$ state with $J^P = 1/2^-$ decays into $\pi\Lambda$ in relative s -wave. Hence, we show in Figs. 6 and 7, the decay angle and energy distributions of the final π^+ , respectively. The solid and dashed curves stand for the contribution of $\Sigma^*(1385)$ and $\Sigma_{1/2}^*(1380)$, respectively. The two curves are normalized to the same area in the range examined. One can see that the shapes of the contributions of $\Sigma^*(1385)$ and $\Sigma_{1/2}^*(1380)$ are very different. From this perspective, the existence of the $\Sigma_{1/2}^*(1380)$ state can be easily checked by future experimental measurements.

As discussed in the *Introduction*, there is a cusp structure or a narrow pole near the $\bar{K}N$ threshold in the $I = 1$ channel [13, 15–17]. This structure may also contribute to the $\Lambda_c^+ \rightarrow \eta\pi^+\Lambda$ decay. However, we expect that its contribution to the $\pi^+\Lambda$ invariant mass distribution should be different from the results shown in Fig. 5, since the structure is cusp like around the $\bar{K}N$ threshold, which could be easily distinguished from a real resonance.

IV. SUMMARY

By considering the contributions from the $\Sigma^*(1385)$ and $\Sigma_{1/2}^*(1380)$ resonances, we studied the $\pi^+\Lambda$ invariant mass, π^+ decay angle and decay energy distributions in the $\Lambda_c^+ \rightarrow \eta\pi^+\Lambda$ decay to understand better the $\Sigma_{1/2}^*(1380)$ state and also the decay mechanism. For the

¹ In obtaining the decay amplitude, we have assumed the factorization of the hard process (the weak decay and hadronization) and the following decays of Σ^* resonances. Such a factorization scheme seems to work very well (see Ref. [36] for an extensive review). We note that a combination of the soft-collinear effective theory and χ PT has been successfully developed to compute the generalized heavy-to-light form factors [37], where a similar factorization scheme is taken but with the hard process calculated in the QCD perturbation theory.

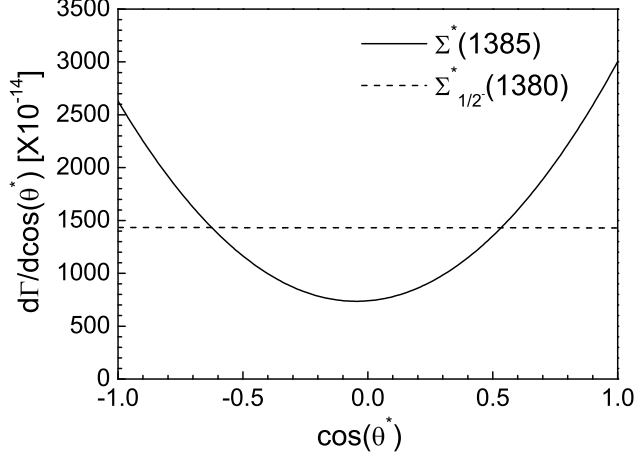


FIG. 6: Angle distributions $d\Gamma/d\cos\theta^*$ in the c.m. frame of $\pi^+\Lambda$ system as a function of $\cos\theta^*$.

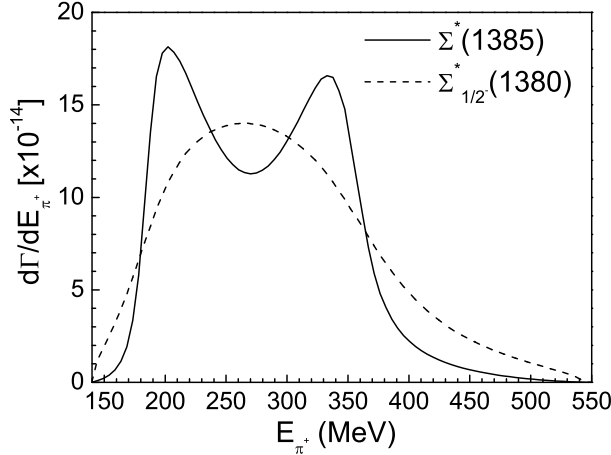


FIG. 7: Energy distributions $d\Gamma/dE_{\pi^+}$ in the rest frame of Λ_c^+ as a function of E_{π^+} .

production of $\Sigma^*(1385)$, the weak interaction part is dominated by the internal W -exchange diagram, while for the $\Sigma_{1/2}^*(1380)$ production, the weak interaction part can proceed via the color-favored external W -emission diagram. This is because $\Sigma_{1/2}^*(1380)$ has a dominant five-quark component. The $\Sigma^*(1385)$ and $\Sigma_{1/2}^*(1380)$ resonances then decay into a $\pi^+\Lambda$ pair.

As evidenced from the line shape of the $\pi^+\Lambda$ invariant mass distribution, the $\Sigma_{1/2}^*(1380)$ state broadens the invariant mass distribution because of its large total decay width. Because the $\Sigma^*(1385)$ and $\Sigma_{1/2}^*(1380)$ resonances have different spin and parity, the final π^+ decay angle and energy distributions are much different.

On the experimental side, the decay mode $\Lambda_c^+ \rightarrow \pi^+\eta\Lambda$ has been observed [3] and the branching ratio $\text{Br}(\Lambda_c^+ \rightarrow \pi^+\eta\Lambda)$ is determined to be $(2.3 \pm 0.5)\%$, which is one of the dominant decay modes of the Λ_c^+ state. Hence, the $\Lambda_c^+ \rightarrow \pi^+\eta\Lambda$ decay can be an ideal process to study the $\Sigma^*(1385)$ and $\Sigma_{1/2}^*(1380)$ resonances. Future experimental measurements of the invariant mass, decay angle and decay energy distributions studied in the present work will be very helpful in illuminating the existence of the $\Sigma_{1/2}^*(1380)$ state and improving our knowledge on its properties. For example, a corresponding experimental measurement could in principle be done by BESIII [38] and Belle [39] Collaborations. Our present study proposed an alternative decay mechanisms for the $\Lambda_c^+ \rightarrow \pi^+\eta\Lambda$ decay and constituted a first effort to study the role of the $\Sigma_{1/2}^*(1380)$ state in relevant processes.

Acknowledgments

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